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Study of Impact of Various Influencing Factors on NMT Mode Choice

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Abstract

In the current study we bring out the impact of various social, economic, environmental, and transportation system characteristics on walk and cycle mode choice, when they are used as a main mode. The environmental factors include density and land use. The impact is determined using a logistic regression model, developed from the house hold survey data of Bangalore city, collected for the year 2009. The results showed a reduced likeliness to walk and cycle, with an increase in travel time using walk and cycle, and individual age. Individuals owning at least a private motor vehicle had less probability of using walk and cycle compared with individuals not owning any private motor vehicle. Females had a positive attitude towards walking than male. Mixed Land-use and increased density had a positive impact on walk and cycle mode use when compared with their reference group.

Key words: walk and cycle; mode choice; environmental factors

1. Introduction

Non motorized transport (NMT), which mainly includes walk and bicycle, has got a number of advantages. Some of their advantage include less congestion; less health, accident and social cost; and reduced infrastructure costs. However, these advantages have not given NMT a place in policy maker's agenda, especially in India. Hook and Replogle (1996) explained how Asian cities are facing an environmental degradation because of the motor vehicle boom, and how the Government policies controlling land-use and density which favor walking and cycling, can form one of the solutions for this issue. According to Plaut (2005) there are at least three reasons why walking and cycling should be promoted over motorized modes. Those are: reduction in car use; planning of

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urban space by promotion of public transit; and social justice and equity (Plaut, 2005). But in India even low income residents are forced to depend on motorized vehicle because of accessibility issue (Srinivasan and Rogers, 2005), thus reducing the social equity. Bolstering the argument supporting the need for high density urban centers, Badland and Schofield (2005), and Chen et al (2008) related this environment factors with increased health and sustainability, among citizens.

Our current study is an attempt to understand the extent of impact of characteristics: socio-economic, transportation network, and environmental; on the walk and cycle mode choice, when they are used as the main mode.

2. Literature Review

Many studies have been done with respect to the impact determination of different factors affecting walking and cycling mode choice. Ortuzar (2000) and Parkin (2008) found a negative relationship between increasing car ownership and bicycle mode choice. Wardman et al (2007) determined a negative effect for age on cycling in Britain, while Plaut (2005) determined a positive influence for age on walking and cycling in United States. Noland and Kunreuther (1995) found a positive likeliness for male in using walk and cycle; on the other hand Agrawal and Schimek (2007) determined a negative likeliness for male to walk. An increase in the travel time using cycle was determined having a reducing impact on the probability of choosing a cycle (Wardman et al, 1997).

Buys and Miller (2011) suggested that perceived transport convenience was modulated by journey destination and purpose, with subsequent impacts on travel mode choice. Supporting this notion Ortuzar (2000) found a positive impact for school purpose for bicycle mode. Other factors influencing NMT mode choice mentioned in studies were the population density and land-use. Badoe and Miller (2000) pointed out the mixed results elicited by various studies on the effect of land-use and density. Cervero (1996) and Cervero and Kockelman (1997) respectively found out a positive correlation between NMT use and mixed land-use, and NMT use and high density. Rodriguez and Joo (2004) arrived at a inconsistent relationship between non-motorized mode choice and increasing density. Rodriguez and Joo (2004) also pointed to the necessity to include certain factors correlated with the environment factors, like vehicle ownership, so that the environmental factors are not over estimated.

In India only few studies has been done for identifying the impact of different factors on walk and cycle usage. One such study was done by Arasan et al (1996) in which the trip characteristics of travelers without vehicles was identified using a logit model. The authors in this study used a set of socio-economic variables and a travel related variable of trip distance in developing the logit model. Another was a segmentation analysis done by Rastogi and Rao (2009) for different modes including an NMT using socio-economic variables and travel related variables. Jain et al (2010) evaluated the influence of bicyclist comfort and safety perception using a route choice model. Other NMT studies mainly pertained to analyzing, walking distance, walking speed, and wand walking flow (Arasan et al, 1994; Rastogi et al, 2011; Rastogi and Rao, 2003; Laxman et al, 2010).

From the above literature review it is clear that there is a dearth of studies for understanding the impact of various factors influencing NMT mode choice in India. No studies are done in India which elicits the influence of environmental factors. Our study tries to put some light on this issue. We develop a logistic regression model using a set of socio-economic, transportation network, and environmental variables; and try to bring out the extent of their effect with respect to their variation, in walk and cycle mode choice.

3. Methodology

A logistic regression is used in estimating the extent of influence of variables when walk and cycle are used as the main mode. The model was estimated using the software biogeme (Bierlaire, 2003; Bierlaire, 2008). The estimation of model was done using the estimation tool and sample aggregation was done using the simulation

tool in Biogeme. The various factors include demographic characters of sex, level of education, age, household income, private vehicle ownership, whether the purpose of trip is to school; transportation system characteristic of time of travel by walk or cycle; and environmental characteristics of population density and land use. The land use here is expressed as a ratio of the employment and population in the origin zone of a trip. An arbitrary range of this ratio between 0.8 and 1.1 is used to classify the land use as mixed. If this ratio is less than 0.8 we attribute population to be more than employment in that zone and deem it as a residential zone. Conversely if ratio is more than 1.1 we consider it as a zone were employment opportunities are more than residing opportunities. Cervero (2002) used a land use diversity variable with respect to the origin zones trips. This was determined as retail employment and population relative to countywide ratio. In our current study logistic regression is done for both walk and cycle separately. Captive riders are deleted from the trip data. The travel time of walk and cycle modes when they are not the chose mode are found out by dividing distance travelled with average speed of walk (0.0719 Kilometer/Minute) and cycle (0.146 Kilometer/Minute), determined from the current data.

Binary logistic regression is a technique which is employed to determine the influence of continuous or categorical variables on the probability of choosing an option. In the current study we use categorical variables. The option usually is ‘yes’ or ‘no’. In our study the option is whether NMT is chosen as the mode or not for a particular trip.

Table 1. Variable categories, their reference and mean

Variable	Categories	Reference case	Mean	
			Walk	cycle
Travel time	Over 20 minutes	20 minutes or less	0.31	0.39
Age	18-50	18 years or less	0.75	0.86
	Over 50	18 years or less	0.10	0.12
Gender	Male	Female	0.77	0.80
Education level	literate	illiterate	0.84	0.86
House hold income	5000 Rupees-20000 Rupees	5000 Rupees or less	0.57	0.87
	Above 20000 Rupees	5000 Rupees or less	0.02	0.02
Private motor vehicle ownership	1 or more	none	0.34	0.37
School-purpose	Yes	No	0.24	0.01
Population density (Population/Kilometer$^{2)}$	25000-50000	25000 or less	0.37	0.37
	Above 50000	25000 or less	0.17	0.18
Land-use (employment/population)	0.8-1.1	Less than 0.8 & above 1.1	0.08	0.08

$$Pr\ (yes) = 1/\ (1+e^{logit}\ ) \quad (1)$$

$$Pr\ (No) = 1-\ Pr\ (yes) \quad (2)$$

Pr (yes) and Pr (No) represents the probability that a NMT mode is chosen or not chosen for a particular trip. e^{logit} represents an exponential function of logit. The term 'logit' is a function which is a linear combination of variables and parameters. The parameters are estimated through maximum log likelihood estimation. The antilog of the parameter will give the odds ratio. In case of a categorical variable odds ratio represents the percentage increase or decrease in the odds of one category a variable over the other category of the same variable. Table 1 defines the various categories of each variable along with their mean representation in the total observations (number of observations in a category/ total observations) and the reference category for each variable.

4. Data source and description

House-hold travel data of the city of Bangalore for the year 2009 obtained through secondary sources is used in our study. Data from 63 zones are used for model estimation. The primary data collection was done by household interview, in which the details of traveler related variables, mode related variables, trip context variables, and environmental variables were collected. Bangalore is a plateau with roads having gentle to medium gradient, and has a pleasant and equitable climate throughout the year. It has got a population of 8 million (Comprehensive Traffic and Transportation Plan for Bangalore, 2007). The area of Bangalore metropolitan region is around 8000 sq km of which 2191sq km is in the urban districts.

Details collected in secondary data included personal characteristics of age, gender, occupation, education level, marital status etc; house hold characteristics of income, number of earners, type of residence etc; and trip characteristics like in vehicle travel time, mode used, purpose, travel distance etc. The major trips were detailed along with their stages and modes used in those stages. For e.g. a work trip using public transit from home was represented as an access stage using walk and an in-vehicle stage using public transit. We obtained 11,822 house-holds from the 63 zones. In the data 55% was males and 45% females. 22% had an age less than 18 years and 66% an age, 18 to 50. 12% was having an age more than 50. The percentage of households in the income groups less than 5,000 Rupees, 5,000 Rupees-20,000 Rupees, and greater than 20,000 Rupees were respectively 40, 57 and 3. After deletion of return trips and trips with incomplete observation we got 9054 utility trips. Utility trips included trips for purpose work and school with a percentage share of 83 and 17 respectively. In the total trips 39% were made by walk as main mode and 4% by cycle as main mode. Rest was made using motorized modes.

5. Results and discussion

Table 2 and Table 3 gives the model results for walk and cycle respectively along with the odds ratio and change in odds for each category of variables with respect to reference variable. The parameter values of certain variables even after being insignificant were kept as such because they were the best values available for that variable. The logistic model had a predictive capability with an accuracy of 100% and 80.65% for walk mode and cycle mode respectively.

The likeliness to use walk and cycle reduced 68% and 79% respectively when the travelling time became more than 20 minutes. This shows a decrease in affinity towards walking and cycling with travel time increase. An increase in age decreased the likeliness towards walk and cycle mode. Old people (age greater than 50) had 12% and 92% less chance of using walk and cycle respectively. Compared with women men had a reducing effect on probability to walk. But for cycle the inverse was true. Men had an increasing effect on probability to cycle. Similar results were found on gender effect by Agrawal and Schimek (2007) for walk mode and Ortuzar

(2000) for cycle mode. Rise in education level had a negative correlation with walk mode and a positive correlation with cycle mode.

Increase in the income showed a negative effect on the probability to walk and cycle. There was a 79% and 100% decrease in the likeliness to cycle when an individual belonged to income groups 5,000 Rupees – 20,000 Rupees and above 20,000 Rupees respectively. It points to the preference of private vehicle among high income group. Ownership of private vehicles had a reducing impact on the chance of using walk or cycle. It indicate peoples tendency to use their own motor vehicles for their utility trips.

The purpose school indicated a greater chance for students to choose walk mode. In case of cycling the purpose school had a negative impact. But the variable was insignificant with a t-value approximately zero. One reason for this insignificance may be the meager presence of school purpose trips for cycle mode (1%).

Table 2. Model results for walk

Variable	Categories	coefficient	t-statistics	Odds ratio	Change in odds
Constant	_	2.90	11.61	_	_
Travel time (minutes)	Over 20	-1.11	-12.53	0.32	-0.68
Age	18-50	-0.118	-2.69	0.89	-0.11
	Over 50	-0.129	-2.60	0.88	-0.12
Gender	Male	-0.518	-4.27	0.60	-0.40
Education level	literate	-0.240	-1.82	0.79	-0.21
House hold income (Rupees)	5000 -20000	-0.0109	-1.12	0.99	-0.10
	Above 20000	-0.272	-0.85	0.79	-0.21
Private motor vehicle ownership	1 or more	-1.27	-13.84	0.28	-0.72
School-purpose	Yes	0.738	5.04	2.09	1.09
Population density (Population/Kilometer$^{2)}$	25000-50000	0.213	2.17	1.24	0.24
	Above 50000	0.385	2.87	1.47	0.47
Land-use (employment/population)	0.8-1.1	0.891	4.56	2.43	1.43
Null Log Likelihood		-2913.29			
Final Log likelihood		-1716.027			
Likelihood ratio test		2394.541			
Rho square		0.411			

Table 3. Model results for cycle

Variable	Categories	coefficient	t-statistics	Odds ratio	Change in odds
Constant	_	-2.51	-7.14	_	_
Travel time (minutes)	Over 20	-1.58	-11.35	0.21	-0.79
Age	18-50	-1.32	-4.02	0.27	-0.73
	Over 50	-2.58	-5.67	0.08	-0.92
Gender	Male	0.0562	0.35	0.95	0.05
Education level	Literate	0.0977	0.53	0.91	0.09
House hold income (Rupees)	5000 -20000	-1.54	-10.78	0.21	-0.79
	Above 20000	-15.4	-1.03	0.00	-1.00
Private motor vehicle ownership	1 or more	-0.554	-3.98	0.57	-0.43
School-purpose	Yes	-16.9	-0.01	0.00	-1.00
Population density (Population/Kilometer$^{2)}$	25000-50000	0.186	1.32	1.20	0.20
	Above 50000	0.0839	0.47	1.08	0.08
Land-use (employment/population)	0.8-1.1	0.0562	0.23	1.05	0.05
Null Log Likelihood		-3200.95			
Final Log likelihood		-966.859			
Likelihood ratio test		4468.190			
Rho square		0.698			

The likeliness to walk increased with respect to the reference group as the population density grew. There was a positive change in odds of 24% when population density was between 25,000 – 50,000, and 47% percentage for density greater than 50,000. The density showed a weak relationship with likelihood to cycle because of insignificant variables. The likeliness to cycle increased 20% for population density between 25,000-50,000 and 8% for density greater than 50,000. A similar trend was projected by Rietveld (2001), and Rietveld and Daniel (2004). In their study for Netherlands Rietveld and Daniel (2004) showed that the bicycle share at first increase and then decrease, with rising density. Even though they attributed this effect to the competition of public transit inside high density areas of CBD in Netherlands, in case of Bangalore lack of infrastructural provision for cycle

mode in form of cycle paths may also be one factor. Lack of infrastructural provision for cycle at high density area will give rise to an increased conflict with other modes.

The ratio between employment and population in the origin zone of a trip, used as an indicator of land-use, boosted the likelihood to both walk and cycle when their range was between '0.8-1.1'. But for the cycle mode the land-use variable was insignificant pointing to its weak relation with mode choice. More studies are required to establish their significance. Short travel distance for accessing jobs and schools; because of an even mix of population and employment, is one reason why people prefer walking when land-use is mixed.

6. Conclusion

In the current study we determined the impact of various social, economic, environmental, and transportation system variables on walk and cycle mode choice. This impact determination was done using a logistic regression model in which the parameters were estimated using maximum log likelihood. The model predicted the data with an accuracy of 100% and 80.65% for walk mode and cycle mode respectively. The parameters and their sign gave a significant insight in to our understanding of walk and cycle mode choice. Following are the important conclusions obtained.

Walk and cycle had a drastic reduction in the users after 20 minutes. There was a likeliness reduction of 68% for walk and a 79% for cycle. 20 minutes corresponded to a distance of 1.5 kilometers and 3 kilometers respectively for walk and cycle mode. This shows that people prefer walk and cycle for short trips. Low speed and excessive physical effort are two reasons why people prefer walk and cycle only for short distances. Hence the policy makers should concentrate mainly on short distance trips for NMT promotion.

Individuals belonging to high income house hold had a less probability of using walk and cycle. Similarly private vehicle owners also had a less affinity towards walk and cycle. This, points to requirement of a policy level intervention, restricting private vehicles, to promote NMT among high income household and private vehicle owners.

Trips with purpose school had a positive likelihood compared with work on choosing walk mode. There is a huge scope for policy makers to target this section for walk promotion. But one issue which needs to be addressed while focusing on this section is safety. Improved foot ways (Abbas et al, 1996) with good connectivity (Randall and Baetz, 2001) can deal with this issue to a certain extent.

Mixed land-use and increased density had a positive impact on walk and cycle mode use when compared with the reference group, even though for cycle the probability of usage first increases and then decreases, with increase in density. One reason for this decrease at high density may be attributed to the lack of infrastructural provision (Wardman et al, 1997) and thus safety (Hopkinson and Wardman, 1996) for bicycles.

Age is an important factor which decides the choice of NMT for a trip. An increase in age is associated with a decrease in walk and cycle preference.

Our study elicits the effect of different variables on walk and cycle mode choice in Indian conditions. In the current study we have used only limited environmental variables: density and land use. An enhancement in our model can be done incorporating more environmental variables like slope of paths, safety condition, walking/cycling index, land-use variable incorporating neighborhood aspects other than employment (Cervero, 2002) etc. It can form a scope for future research.

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